Introductory Computer Science with Robots

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Introduction

Starting in the fall of 2005 our department began a large-scale effort to incorporate hands-on robotics in many of our courses, including our introductory computer science sequence. This followed the establishment of a departmental robotics laboratory and the purchase of a number of different robots. Our efforts include testing our projects and surveying students about their satisfaction with robots as well as significant software development of an algorithmic programming environment for robotics (Robotran) and an associated robot simulator.

The first two courses in our introductory sequence are a CS0 breadth-first introduction to computer science (CSC 110) and a typical CS1, namely, a first programming course in java (CSC 111). CSC 110 is taken by most incoming computer science majors as well as by a number of students in other majors seeking to fulfill a math/computing general education requirement. Most of the students in CSC 110 have, unfortunately, little interest in the field of computer science. On the other hand, most students in CSC 111 are majoring in a computing-related field, including Computer Science, Bioinformatics, Digital Media Arts, and Mathematics.

There are several reasons for introducing robotics into these courses. One is to interest students in the field of computer science (and specifically, in artificial intelligence), either as possible majors or minors. There is considerable evidence that robots enhance student learning and lead to overall positive experiences in the classroom (Greenwald et al. 2004). An equally important reason is to allow students to see the impact of programs outside the realm of the computer on which they are written.

Computing devices are ubiquitous today and robots provide examples that reinforce this, effectively showing students how they might control these sorts of devices with programs they write. Robots can be used to help teach or reinforce a number of basic computing ideas. These range from fundamental algorithmic notions of selection and iteration to classes and objects (if an object oriented programming language for the robots is employed) and the event driven paradigm.

Robots

Our introductory courses have focused exclusively on the LEGO Mindstorms platform (Klassner 2002, Lawhead et al. 2003). We developed a very stable chassis design that includes two or three motors, two for powering wheels on each side of the four-wheeled vehicle and an optional additional motor for controlling a pen used for drawing. The robots have three sensors: two bump sensors attached to the front right and left bumpers and a light sensor. The robots were built by faculty with the assistance of upper-level undergraduate student assistants.

Language and Environment

We use Lejos (http://lejos.sourceforge.net), a Java-based programming language for the Mindstorms, for all of our LEGO robot programming. This presents a challenge for CSC 110, where we emphasize basic algorithmic ideas and have conscientiously steered clear of introducing an actual programming language. Recently, CSC 110 students have learned the simple algorithmic language PALGOL (http://www-cs.canisius.edu/~meyer/PALGO/Palgo.html). To overcome the problem of teaching students how to program without introducing the complexities of a traditional programming language we started development of a translator program (Robotran) in the fall of 2005. Robotran allows students to write programs to control the LEGO Mindstorms robots with a Python-like language rather than the more complicated Lejos. Figure 1 shows the text of an extremely simple Robotran program that can be translated into Lejos with the click of a button.

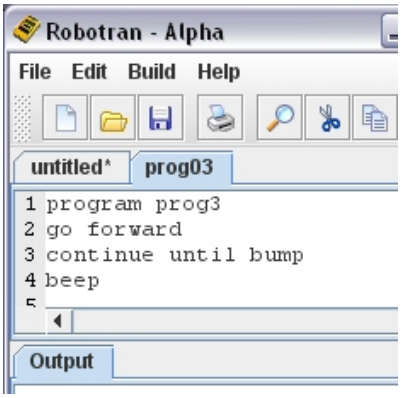

Figure 1. The Robotran Program Window

We are now developing a simulator that graphically displays the LEGO Mindstorms robot executing a Robotran program. This simulator will allow students to test their programs on-screen, possibly at home or in an open computer lab, before downloading to a real robot, which takes time and requires a supervised lab. Figure 2 shows a snapshot of the current simulator.

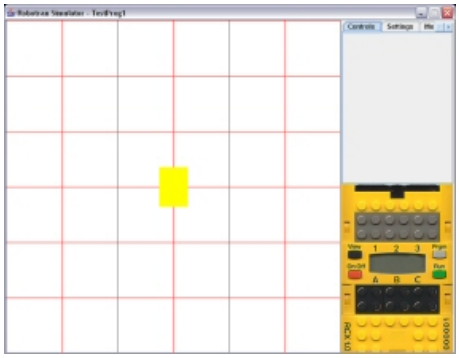

Figure 2. The Robotran/Lego Mindstorms Simulator

Robotran can be accessed on the Web (http://www-cs.canisius.edu/~meyer/ROBOTRAN/home.html).

Projects

In CSC 110 students used Robotran to write programs for robots equipped with an extra motor that controlled a felt-tipped pen (pen up, pen down). These programs required students to come up with algorithms for drawing a variety of letters such as upper case I, H, L, X, and P. Students worked in class in groups of 4 and wrote programs for each letter. The class sat in a circle and watched as each group's program was run on a robot that drew the letters on a large sheet of newsprint. Some of the groups were unable to draw their letter on the first attempt. The group was then allowed to think about what went wrong and discuss (and implement) possible corrections.

In CSC 111 students used Lejos directly for programming robots. The course has two lab sections of approximately 16 students each. This allows each student to work with his or her own robot, which we have come to realize has been an important part of the success we are currently having with this new 4-week course component. The robots are only available during one 50-minute closed laboratory per week, a problem that the availability of the simulator will help alleviate in the future. Students have written programs to move the robots in various patterns, back away from detected obstacles, follow a flashlight, and will be working on a mapping project that will introduce and help motivate the need for arrays.

Results

We have collected quantitative and qualitative data (fall 2005, CSC 110) and will survey the CSC 111 class at the end of this semester. Overall reaction has been positive. We surveyed three CSC 110 classes with a total of 56 students in fall of 2005. 59% said working with robots helped them understand algorithms; 64% said working with robots helped them understand programming; 71% said we should include more robotics material in the course; 79% said they liked working with robots; 66% said they would choose an AI/robotics version of the course over the current "vanilla" offering.

With the addition of robotics in CSC 111 we saw an even greater appreciation for programming on the part of students this year. In the lab, all students, including both the stronger and the weaker students, wrote and downloaded robot programs with intense concentration to the point that it was hard to get them to leave when the lab time officially ended. Several students asked how to buy their own robots.

References

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